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At the onset of settled pastoralism – Implications of archaeozoological and isotope analyses from Bronze age sites in the North Caucasus

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ABSTRACT

Bioarchaeological studies provide a valuable contribution to the understanding of the economy and activities of prehistoric populations in mountain regions. The Late Bronze Age in the Caucasus is an epoch of fundamental transformations that is accompanied by the development of a semi-stationary pastoral economy and ultimately by the emergence of combined mountain agriculture. So far, only a few archaeozoological assemblages from this period have been published. The site of Ransyrt-1 in the North Caucasus offers a substantial collection of bone material from the remains of a mountain sanctuary. Analysis of the animal remains as well as preliminary isotopic analyses of strontium, oxygen, and carbon shed light on animal exploitation at this site. Comparisons with slightly later settlements in the North and South Caucasus illustrate the development of intensive livestock management strategies in the Late Bronze Age in this region at the interface between Southwest Asia and the Eurasian steppe.

1. Introduction

Mobile and sedentary pastoral economies are the most emblematic economic systems in mountainous regions across Eurasia (Collis et al., 2016). Along with metal and wood, dairy products are highly important commodities sourced from mountain areas. With increasing altitude, the cultivation of arable crops becomes precarious and thus animal husbandry focusing on dairy and meat products is central for a livelihood in a mountain environment. One results of these conditions are vertical mobile herding practices, which were probably developed in the Caucasus as early as the 3rd millennium BCE. In contrast to Western Asia or the South Caucasus, no sedentary, agricultural population is present in the valleys of the Northern Caucasus between the 4th and late 2nd millennium BCE.

The earliest seasonal use of mountainous pastures in the Alps dates to the early Middle Bronze Age in the mid-2nd millennium BCE (Nicolis et al., 2016). In the Altai Mountains, archaeological and bioarchaeological evidence points to seasonal exploitation of highland pastures as early as the late 4th millennium BCE (Svyatko et al., 2017). In the Caucasus, pastoral economies based on dairy products formed even earlier during the late 5th millennium BCE (Scott et al., 2022). This area plays a crucial role in the introduction of animal herding to Eurasia. Crossing the Caucasus is one of only a few routes for grassland adapted domesticates such as sheep, goat, and cattle to be dispersed from their domestication centres in Western Asia into and Europe (Berthon, 2014; Zeder, 2017). Moreover, Caucasian mountain valleys and highlands are characterised by a biologically highly divers environment. The interfaces of mountain and steppe ecozones offer excellent pasture for maintaining large herds (Spengler et al., 2013).

Economies based on animal-derived products and draught labour

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emerged in the Caucasus and its neighbouring steppelands parallel to the introduction of a Neolithic lifestyle, which included crop cultivation and sedentism. It was introduced in the 6th millennium BCE in the South Caucasus related to the Shomutepe-Shulaveri Neolithic culture (Berthon, 2014) and in the second half of the 5th millennium BCE in the North Caucasus, e.g., at Eneolithic sites such as Meshoko and Meshoko rock shelter (Ostashinsky et al., 2016). First direct evidence of dairy product consumption is based on milk proteomes extracted from dental calculus and was found in Eneolithic individuals also dating to the late 5th millennium BCE. Surprisingly, for two millennia only the milk of sheep was exploited in the North Caucasus, as evidenced by the findings of eight individuals in burial mounds of the Early Bronze Age (EBA) Maykop culture from the 4th millennium BCE, and of three individuals in contexts of the EBA Yamnaya culture from the early 3rd millennium BCE, whereas the use of cow's milk was first documented at the end of the 3rd millennium BCE in late Yamnaya and North Caucasian culture contexts (Scott et al., 2022). Stable carbon and nitrogen isotope data of bone collagen equally confirm a high importance of animal-derived foodstuffs starting from the 4th millennium BCE (Knipper et al., 2020). Eneolithic and EBA societies associated with this initial form of pastoral animal husbandry oscillated between mobile and sedentary agro-pastoral lifestyles (Shishlina, 2013). Settlements and indicators of agriculture and animal husbandry are present in the Caucasus foothills and foreland, but hundreds of burial mounds without settlement evidence in the steppe zone indicate a more mobile environmental exploitation. The late 4th and the 3rd millennium BCE Middle Bronze Age (MBA) witnessed increasing mobility in the North and South Caucasus, which can be inferred from the fact that settlement evidence is coming to an end, although simultaneously large numbers of burial mounds were built (Shishlina, 2008; Sagona, 2018, 289–325). From this time onwards, mobile pastoralism dominated Bronze Age economies for more than a millennium including the widespread use of mid- and high

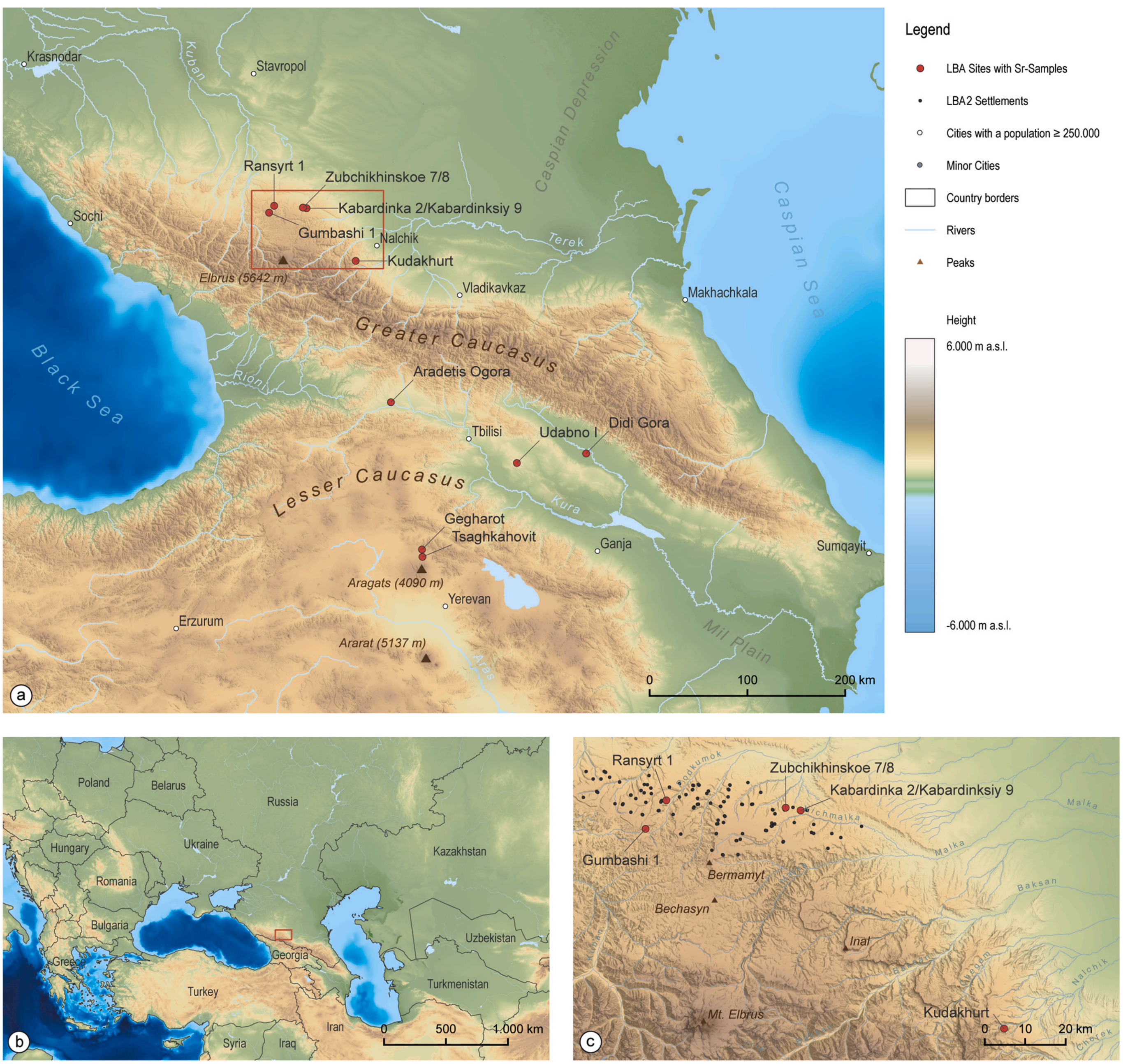

Fig. 1. Map of the Caucasus area. A Sites mentioned in the text, b Location of the study area, c The Caucasian Mineral Waters area with the studied archaeological sites. Archaeological data from Reinhold et al. (2017), fig. 157.

mountain areas (Reinhold et al., 2023). This changed again radically at the beginning of the Late Bronze Age (LBA) in the first third of the 2nd millennium BCE, when a resettlement process started. Numerous small settlements and burial features emerged in the mountainous landscapes in the South Caucasus (Smith et al., 2009) and also in some parts of the North Caucasus (Reinhold et al., 2017). These communities combined mountain agriculture and semi-stationary animal husbandry. An inevitable consequence was the transformation of animal herding practices, an increase in managed herd size, and changes in human-animal interactions. In the area of our case study, more than 280 settlements, enclosures and other pastoral architecture were documented through aerial photographs and systematic surveys. Many of them proved to be contemporaneous. They allow the calculation of herd quantities via the area of animals to be sheltered in multifunctional houses and enclosures. Livestock population quantities were probably similar to that recorded for the region in the 19th century (Reinhold et al., 2017).

Here, we present new data from the onset of this economic and social reorganisation in the high mountain zone of the North Caucasus (Fig. 1). The ritual site of Ransyrt-1 spans a settlement sequence from the 18th to the 16th century BCE and represents the historical watershed between the mobile herding communities of the MBA as well as sedentary and semi-mobile herding practices of the LBA.

This paper investigates animal management practices in a high mountain environment through archaeozoological and isotope analyses. A pilot study that employs multi-isotope ($\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) analysis of sequentially sampled tooth enamel allows to explore life histories of animals consumed at Ransyrt-1. For this initial investigation, we have selected teeth of three cattle individuals as the most prominent species at the site. In mountain sites, sequential sampling along high-crowned teeth of herded domesticates can be expected to offer insights into vertical transhumant pasture strategies used by the communities which contributed to the food remains (Hermes et al., 2018; Makarewicz et al., 2017; Chazin et al., 2019). The results are discussed in relation to animal bone assemblages from slightly later settlements in the vicinity (Antipina, 2011, 2017) and the South Caucasus (Uerpmann and Uerpmann, 2008; Chazin, 2016; Barbiero and Rova, 2020).

2. Ransyrt-1 – an early Late Bronze Age ritual site in the North Caucasus

Ransyrt-1 is a walled enclosure of about 300 m in diameter situated at ca. 1800 m asl on a plateau south of the Caucasian Mineral Waters area near the modern town of Kislovodsk. The enclosure is built at the cliff atop a gorge overlooking one of the most important passes in the central part of the North Caucasus passing Mt. Elbrus (Fig. 2a-b). It is characterized by three semi-circular walls framing a central area. A magnetometer survey revealed evidence for highly disturbed soils pointing to an intense use of the site (Reinhold et al., 2017, 185–191).

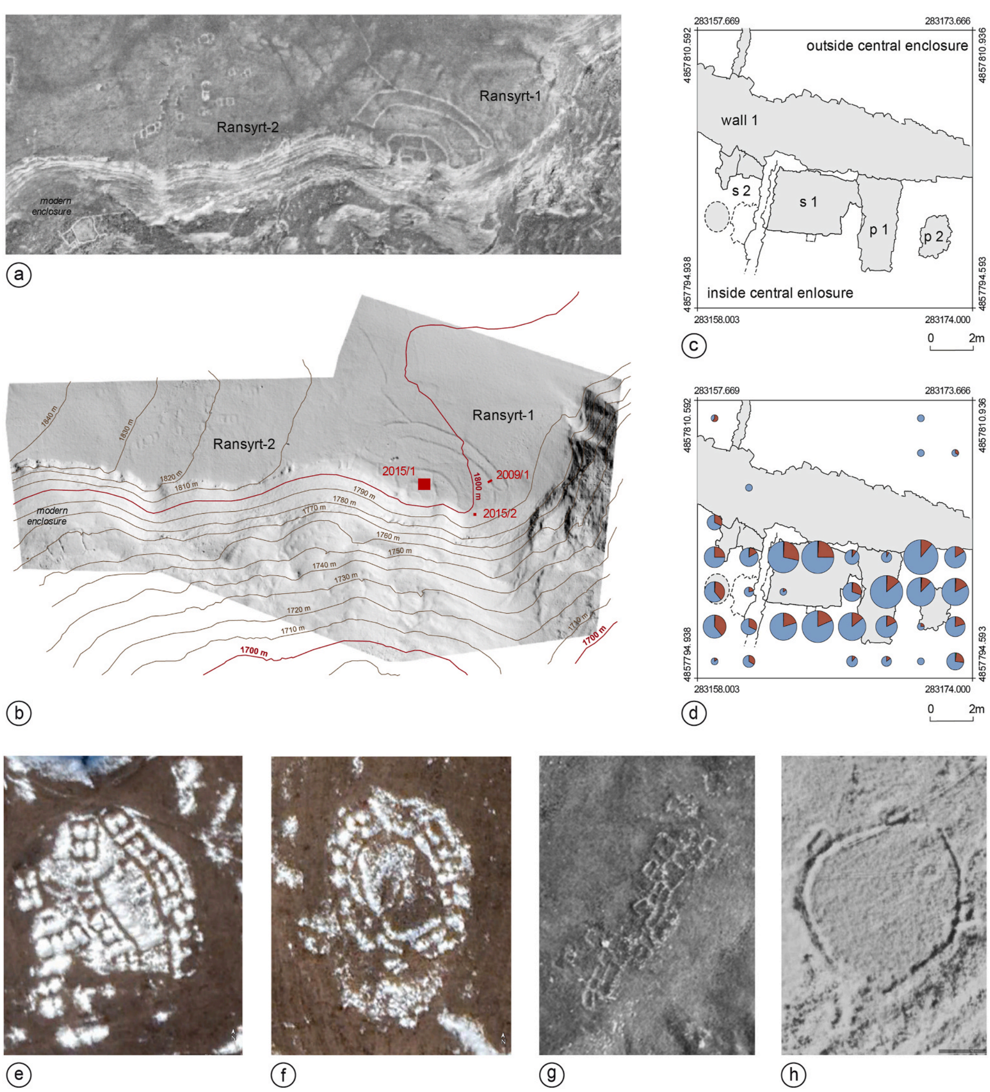

Fig. 2. LBA sites in the North Caucasus study area. A Ransyrt-1, aerial image of the walled enclosure and nearby sites, b topography of Ransyrt-1 and excavated areas, c Excavated features in trench 2015/1 (wall 1 = enclosure wall, s1 = structure 1, s2 = structure 2, p1 = platform 1, p2 = platform 2), d Distribution of animal bones by species from horizons 3–6 in trench 2015/1 (blue = Cattle, red = Sheep/Goat, green = Horses), e Kabardinka-2, satellite image, f Zubchikhinskoe-7, satellite image, g Gumbashi-1, aerial image, h Circular enclosure Gudgora-2, satellite image in grayscales. Satellite images from © GoogleEarthPro, DAI licence.

Excavations in 2015 exposed a small sunken room (structure 1), two well-preserved platforms (platform 1–2) and a poorly preserved walled construction (structure 2), most likely used for ritual activities (Fig. 2c). This interpretation is based on the layout of these structures, large quantities of archaeological finds inside the central enclosure reflecting substantial consumption, the deposition of the related materials at the spot (Fig. 2d), and evidence of intentional 'closing' of the ritual area (Reinhold et al., 2020). The quantities of animal bones that can be classified as accumulated slaughter waste, raise the question whether and to what extent animals were kept in the immediate vicinity of the site. They could have just been consumed there.

The archaeological layers at Ransyrt-1 are dated by 17 stratified radiocarbon dates and define the early Late Bronze Age (LBA 1) in the region. The stratigraphy indicates four main stages of use: 1.) the building of stone constructions and enclosure walls along with the active use of the area; 2.) a terminal event of the ritual activities, which resulted in the deliberated burning of the ritual structures; 3.) piling up rubble into a tumulus to cover the underlying structures; 4.) fireplaces were excavated on top of the stone cover, representing a final act or a later reuse of the site (Table 1).

Outside the central area, excavations in 2009 (Fig. 2b) revealed fireplaces associated with mobile architecture between the enclosure walls. The magnetometry plan shows hundreds of those fires, indicating constant or repeated use of the areas by a considerable number of people, perhaps using mobile architecture such as tents.

3. Material and methods

3.1. Archaeozoological methods

Excavations conducted in the summer of 2015 at Ransyrt-1 have produced abundant animal remains. A total of 36,281 specimens are documented from an excavation area of 256 m^2. About half of the recovered animal remains originate from areas referred to as structure 1, structure 2, and platforms 1–2 (Fig. 2c). They are associated with the principal activities at the site, or archaeological horizons 4–6. The other half accounts for specimens of other features from the upper layers (1–3) in the same area of the excavation (Tables 1 and 2).

Quantification of the animal bone assemblage is based on the number of identified specimens (NISP). Further quantitative analyses include the distribution of relative bone weights to assess skeletal representation of the main domestic species. The weights of skeletal elements in complete reference skeletons were taken as standards (Reichstein, 1994). Slaughter ages were established by the eruption and wear of the teeth and by epiphyseal fusion. Tooth eruption and wear was recorded using data published by Habermehl (1975, 1985). The state of closure of the epiphyses (unfused or fused) was recorded and linked to an absolute age after Zietzschmann, Krölling (1955, 363). The sex of animals was established based on the shape of pelvises for cattle and for sheep or goat based on horn cores and pelvises (Boessneck et al., 1964). Osteological measurements were recorded according to Driesch (1982). Sheep and goats were distinguished using criteria for postcranial skeletal elements (Boessneck et al., 1964; Zeder, Lapham, 2010).

Pathological changes to bones were noted. Since wither heights cannot be calculated, the "Logarithmic Size Index" (LSI) technique (Meadow, 1999) was applied for a stature analysis of cattle and sheep. Measurement values of recent skeletons published by Manhart (1998) were used as a standard. Data is reported in Suppl. Information 2.

The presence of butchery marks was noted and heat exposure recorded as traces of burning, partially charred, completely charred, partially calcined and calcined. Bones showing signs of working were recorded as such.

3.2. Stable isotope analysis

Stable isotope analyses are widely used in studies of past animal husbandry practices (e.g. Towers et al., 2011; Vaiglova et al., 2018; Ventresca Miller and Makarewicz, 2018). For this pilot study we use oxygen ($\delta^{18}O$), carbon ($\delta^{13}C$) and strontium ($^{87}Sr/^{86}Sr$) to address questions related to mobility, seasonality, locality, and diet. A selection of cattle teeth was sampled sequentially and the $\delta^{18}O$ data investigated for birth seasons using the method developed by Balasse et al. (2012a) and Balasse et al. (2012b). Suppl. Information 1 gives a detailed overview of the methodological background of the analytical approaches.

3.2.1. Investigated samples for isotope analysis

We sampled one tooth each of eight cattle, four sheep and four pigs from Ransyrt-1 for strontium isotope analysis. All ruminant teeth are lower third molars, the pig teeth are upper third molars or undetermined. Three left lower third molars of cattle were selected for sequential sampling to determined $\delta^{13}C$ and $\delta^{18}O$ values of the structural carbonates in order to obtain information about the potential origin of these animals at this outstanding site, i.e. whether they were kept locally or sourced transregionally as sacrificial animals (see Suppl. Information 3).

Lower third molars of cattle are formed between 9 and 23 months (Brown et al., 1960), with another 6 months before mineralization is complete (Balasse, 2002). Thus, the sampled teeth provide information on the second and early third year of the animals' lives.

For comparison, we included one cattle and one sheep tooth from the earlier burial ground of Kabardinsky-9 (MBA, 25th cent. BCE), six cattle teeth as well as eight sheep/goat teeth from the younger sites of Kabardinka-2, Gumbashi-1, Zubchikhinskoe-7 and 8 (LBA 2, 14th to 10th cent. BCE), as well as two sheep/goat teeth and a carnivore (wolf?) tooth from the site of Kudakhurt (final MBA, 22nd-19th cent. BCE) in ca. 120 km distance. The crowns of two cattle and three sheep/goat teeth were sampled at two positions with a distance of ca. 2 cm, which allowed for a cost-efficient detection of possible variation of the Sr isotope compositions along the teeth (Knipper, 2011). Since teeth of herbivores such as cattle, sheep and goat mineralize incrementally over several month, they have the potential to provide records of changes in the isotopes (Wiedemann et al., 1999; Hoppe et al., 2004).

Table 1
Chronology, stratigraphy, and principal activities at the ritual site Ransyrt-1.

Dating	Archaeological context	Studied features
ca. 1800-1600 cal. BCE horizons 4-6	construction of the walls construction and active use of the sunken room and the platforms in the central area use of the area between the walls for mobile architecture	Structure 1, 2 and platforms 1, 2
ca. 1600/1550 cal. BCE horizon 3	covering structure 1 and the area between the platforms with wooden planks, placing large vessels side by side and controlled burning of the assemblages	
ca. 1600/1550 cal. BCE horizon 2	covering of the burned structures with gravel	other features
after 1600/1550 cal. BCE horizon 1	re-use associated with small fires places on top of the stone cover	

Table 2
Species distribution for studied contexts and the total material quantified in terms of number of identified specimens (NISP) and bone weight (in grams) at Ransyrt-1.

Species	Structure 1		Structure 2		Platforms 1-2		other features		Total	
	NISP	Weight	NISP	Weight	NISP	Weight	NISP	Weight	NISP	Weight
Domestic mammals										
Cattle	1127	15,873	657	12,681	2837	45,557	4298	64,729	8919	138,840
Sheep/goat	359	1632	227	1744	521	1990	1219	5655	2326	11,021
(thereof sheep)	(47)	(389)	(31)	(616)	(47)	(360)	(108)	(1220)	(233)	(2585)
(thereof goat)	(1)	(6)	(–)	(–)	(3)	(35)	(11)	(143)	(15)	(184)
Pig	3	7	3	34	6	17	19	153	31	211
Horse	6	99	1	19	3	108	7	106	17	332
Dog	1	1	–	–	–	–	–	–	1	1
Wild mammals										
Red deer	2	17	–	–	2	8	1	17	5	42
Fox	–	–	–	–	2	4	–	–	2	4
Hare	1	1	1	2	5	10	3	9	10	22
unidentified	3633	9947	978	2498	7690	18,530	12,669	29,767	24,970	60,742
Total	5132	27,577	1867	16,978	11,066	66,224	18,216	100,436	36,281	211,215

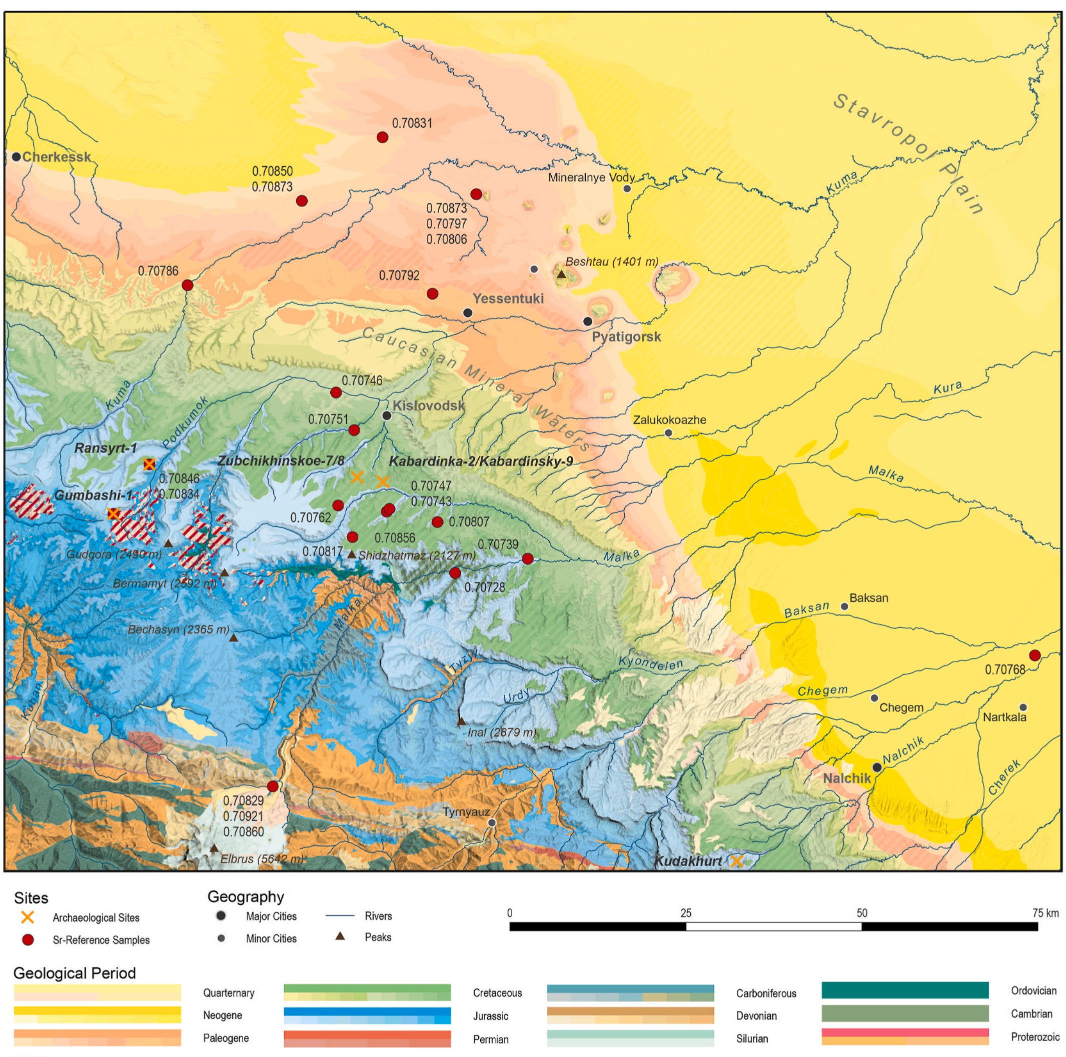

Fig. 3. Geology of the wider study area, archaeological sites and strontium isotopic baseline values. Digital elevation model based on Shuttle Radar Topography Mission 1 Arc-Second Global, data of modern settlements, mountain peaks, and watercourses from OpenStreetMap. For details of the simplified geological map see Suppl. Information 1.

In order to characterize the isotopic composition of the biologically available strontium in the study area, the teeth of two sousliks from Ransyrt-1, a probable marmot bone as well as 19 modern snail shells and five plant specimens from various locations were sampled (Suppl. Information 4). The upland locations are outside the farming zone. Samples from lowland locations were collected in forests to minimize modern contamination. Sampling took place parallel to the LBA settlement survey in 2009–2013 and thus covered chiefly the area with archaeological sites and their direct surroundings. The wider region was sampled less intensively.

Sampling, chemical preparation and measurement followed established procedures (Knipper et al., 2018) and are outlined in Suppl. Information 1.

3.3. Geology and environmental conditions of the North Caucasus

The Caucasus is a late Cenozoic orogenic mountain system at the collision zone of the Arabia-Eurasian lithospheric plates (Adamia et al., 2011). In the central mountain range of the Great Caucasus, the main Caucasian fault led to an uplift of up to 4000 m asl. A series of intersecting stratovolcanoes, such as Mt. Elbrus (5642 m asl) or Mt. Kazbek (5047 m asl) tower up about a thousand meters more. They are of Neogene-Quaternary origin (Lebedev et al., 2010) and situated within the ragged high-mountain zone of Proterozoic granitoids cropping out in the centre of the mountain chain. Mid-mountainous terrains and valleys to the North and South are characterized by gently rising lime- and sandstone plateaus of Jurassic and Cretaceous age. They are intersected by deep gorges with cliffs that drop vertically for a hundred meters and more, as for example near Ransyrt-1. The Caucasus foreland is characterized by a hilly or flat terrain and massive loess accumulations of Quaternary age that covers older formations (Konstantinov et al., 2022).

The investigated sites are located on plateaus formed by the Cretaceous and Jurassic limestone and sandstone formations, whose weathering products influence the biologically available strontium (Fig. 3). Singular samples originate from possible Late Devonian and Proterozoic rocks in the high mountains (for details of sampling locations see Suppl. Information 4).

The Great Caucasus is bordered by the Black Sea to the West and the Caspian Sea to the East. Central parts of the mountain range are covered by glaciers. The Kuban and Terek riverine system drain the northern slope, Rioni, Aragvi and Iori drainages are situated at the southern slope. Today, climatic conditions are temperate with alpine vegetation at high elevations and a mixture of mountain forests and meadows in the valleys. The piedmont plain is forest and herb steppe (Bohn et al., 2007). Precipitation and humidity decrease towards the east, which results in largely forestless mountain slopes in Dagestan. In the early 2nd millennium BCE, the region was likely slightly more humid than today with forests covering the mountain slopes (Connor, Kvavadze, 2009).

Our study area is located between the Kislovodsk Basin and the lower parts of the Mt. Elbrus massif along a historic route (Fig. 1c). The potentially exploited landscape includes the foothill steppe on various Paleogene and Neogene sediments or Quaternary loess, the lower and mid-range mountain zones located on Cretaceous and Jurassic plateaus, as well as the high mountain zone with outcrops of Proterozoic rocks and much younger volcanic formations.

4. Results

4.1. Archaeozoological analysis

4.1.1. Identified animal species and general overview

31% of the material (n = 11,311 bones/bones or teeth) were taxonomically identified (Table 2). Only mammalian species were present, with cattle and sheep/goat representing the majority of the specimens. Unidentified fragments (n = 24,970) are mainly small pieces with an average weight of 2.4 g.

Preservation of the bones varies. Items found near the surface are heavily corroded in most cases. Those from deeper layers are slightly better preserved. However, the surfaces of these bones are also severely affected. Most of the bones are highly fragmented. The actual butchering process is not clear as only one bone, a right cattle astragalus, exhibited clear chop marks. The high degree of fragmentation is an indication that they are primarily remains from the slaughter of animals, their preparation into food, and finally their consumption. A total of 354 pieces show traces of exposure to fire and most of them are heavily carbonized.

Domestic mammals are represented by cattle, sheep, goat, pig, horse

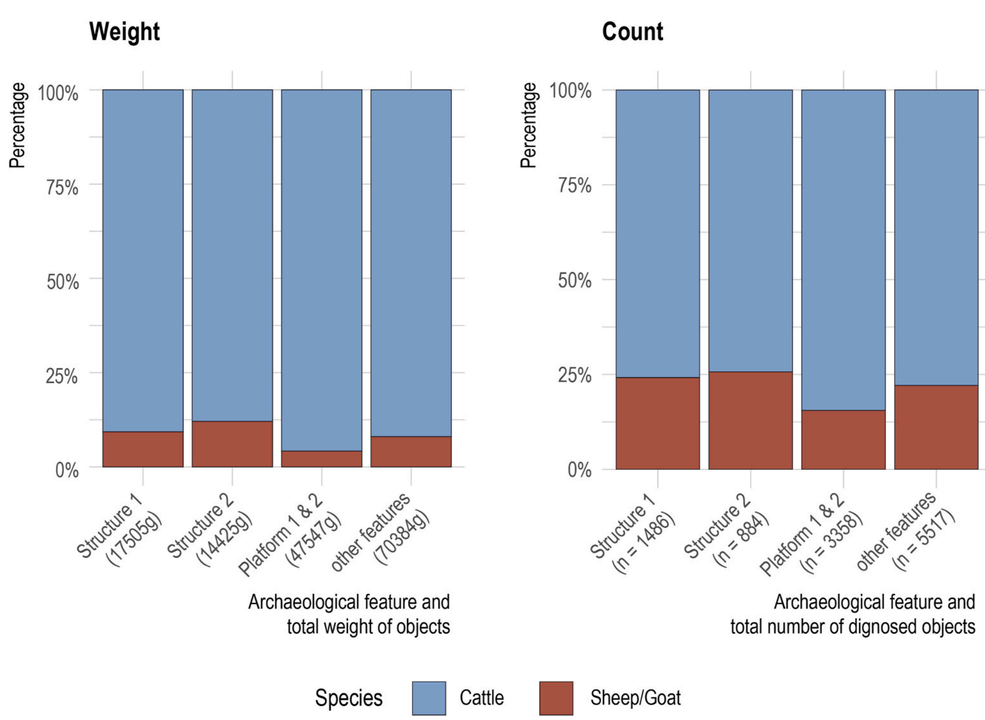

Fig. 4. Relative frequency of cattle and sheep/goat in different features of Ransyrt-1 (cf. Table 2).

and dog (Table 2). The most common species is cattle with a total of 8919 identified fragments. Cattle make up 79% of the assemblage of domestic mammals, and 92% by bone weight. Faunal inventories across the studied archaeological contexts differ only slightly (Fig. 4).

The material from platforms 1 and 2 contains the highest proportion of cattle. Domestic caprines - sheep and goat - are the second most frequent group among domestic mammals. A total of 2326 bones and teeth were assigned to these two species (Table 2; Fig. 4). This corresponds to a proportion of 20% of domestic mammals identified. Species identification was achieved for 248 specimens, of which 233 are assigned to sheep and 15 to goats. This gives a ratio of 16:1 and shows a clear dominance of sheep.

Only 31 bones or teeth of pigs were found among the animal remains of Ransyrt-1. Apart from a few postcranial bones, these are remains of the skull, mainly isolated teeth (Table 2). Two maxilla fragments document two young-adult individuals, and one mandibula fragment comes from an animal estimated to be three to six months old. Five fragments of mandibular canine teeth were assigned to male pigs. Two of the pieces represent worked artefacts.

There is a total of 17 bones fragments of horse across all skeletal regions. As far as it can be determined, they originate from adult animals. Bone fragmentation of the postcranial skeleton is similar to that of cattle. Pig and horse bones stem from a limited area south of platform 2. Finally, one rib fragment of a dog is documented, but may represent an accidental intrusion.

Wild mammals are represented by only three species in Ransyrt-1: red deer, fox and hare (Table 2). They account for a total of only 17 finds. There are three antler fragments of red deer as well as a fragment of a radius and thoracic vertebra. Two lumbar vertebrae were assigned to adult foxes. Ten hare bones are distributed as follows: radius 1, pelvis 2, femur 3, tibia 1, talus 1, costa 2. All bones belong to adult animals.

4.1.2. Age structure and sex ratios of cattle and sheep/goat

Age determination for cattle was possible on 50 mandibles; only two (4%) belong to juveniles (under 14 months) and five specimens (10%) stem from young adult animals (under 3 years) while older adult individuals account for 86% of the mandibles (n = 43) (Table 3). Within this group, younger animals are in the majority, since almost all the mandibles with identified third molars show a low degree of wear.

Observations on the stage of epiphyseal fusion of postcranial elements confirm the dominance of adult animals among domestic cattle (Table 4). The data shows that in the first three age stages, skeletal elements with fused epiphyses clearly predominate, that is, these bones belong to animals older than the respective age stage and hence were not slaughtered in the first years of life. Between the two age stages of 24–36 and 42–48 months, we can observe the highest increase in the proportion of animals slaughtered (from 27 to 63%) (Fig. 5a).

Table 3
Age distribution of cattle and sheep/goat based on mandibles at Ransyrt-1.

	Cattle		Sheep/Goat	
Criteria	Estimated age	Count	Estimated age	Count
Milk premolars erupting	prenatal – 3 weeks	–	prenatal – 4 weeks	–
Milk premolars erupted	up to 3 months	–	1–2 months	–
M1 erupting	4–6 months	–	3–4 months	–
M1 erupted	7–14 months	2	5–8 months	5
M2 erupting	15–18 months	2	9–11 months	2
M2 erupted	19–24 months	2	12–17 months	20
M3 erupting, P changing	25–28 months	1	18–24 months	2
P2 and P4 changing	29–34 months	–		1
M3 and premolars erupted	over 3 years	4	over 2 years	10
Permanent dentition:				
M3 slightly – moderately worn		31		44
M3 heavily worn		5		6
M3 very heavily worn		3		3
	Total	50	Total	93

Table 4
Age determinations of cattle and sheep/goat on elements of the postcranial skeleton at Ransyrt-1. Numbers of elements with unfused or fused and fusing epiphyses.

Cattle			Sheep/Goat		
Age of fusion skeletal element	unfused	fused	Age of fusion skeletal element	unfused	fused
ca. 12–20 months			ca. 3–4 months		
Humerus, distal	7	72	Humerus, distal	4	51
Radius, proximal	2	116	Radius, proximal	1	50
	5%	95%		5%	95%
ca. 20–24 months			ca. 12 months		
Phalanx 1, proximal	5	23	Phalanx 1	3	18
	18%	82%		14%	86%
ca. 24–36 months			ca. 18–24 months		
Tibia, distal	10	63	Tibia, distal	14	16
Calcaneus (Tuber)	30	35	Metapodial, distal	26	10
Metapodial, distal	16	57	Calcaneus (Tuber)	35	18
	27%	73%		63%	37%
ca. 42–48 months			ca. 36–42 months		
Humerus, proximal	28	9	Humerus, proximal	15	5
Radius, distal	25	20	Radius, distal	16	3
Ulna, proximal	18	7	Ulna, proximal	16	5
Ulna, distal	7	2		78%	22%
Femur, proximal	22	15	Femur, proximal	24	15
Femur, distal	31	24	Femur, distal	6	4
Tibia, proximal	53	33	Tibia, proximal	19	4
	63%	37%		68%	32%
ca. 48–60 months			ca. 48–60 months		
Vertebra (corpus)	338	91	Vertebra (corpus)	112	21
	79%	21%		84%	16%

Based on the age assessments of the mandibles and the data on epiphyseal fusion, most cattle were slaughtered when fully grown. Judging by the degree of fusion of the vertebral plates, only about 20% of the cattle represented in the material reached an age older than five years.

Sex ratios of cattle based on the shape of 75 pelvises show that 36 belong to female and 39 to male animals. According to morphological criteria, most of the male pelvises are likely from castrates. In total, an overall balanced ratio of the sexes is evident.

Age determination for sheep/goat was possible on 93 mandibles; 7 (8%) belong to juvenile animals (up to 11 months), 23 (25%) to hoggets (12–24 months), and 63 (67%) to adult animals (over 2 years) (Table 3; Fig. 5b). Accordingly, the majority of caprines represented in the bone assemblage appears to have been slaughtered at an older age. Among the older animals with permanent dentitions, rather younger age stages are represented, given that most of the mandibles show only slight use of the third molars. Remarkable is the frequent occurrence of mandibles with erupted second molars (n = 20). These specimens probably primarily represent animals that were slaughtered in the second half of their second year of life. The general trend for age groups determined from elements of the postcranial skeleton are largely consistent with the observations for mandibles (Table 4). There is a noticeable increase in the proportion of animals slaughtered between the ages of 12 and 18–24 months (from 14 to 63%).

Sex identification of sheep is based on both horn cores and pelvises, whereas only a few horn cores of goats were available for sexing. Among the 16 pelvises of sheep, two belong to female and 14 to male individuals. The latter are mainly from wethers. Five horn cores of sheep belong to four male animals and one female, while four horn cores of goats represent two female and two male animals.

4.1.3. Skeletal element distribution of cattle and sheep/goat

For cattle and caprines, comparing the frequency of the skeletal elements identified among the inventory of Ransyrt-1 (Table 5) to the

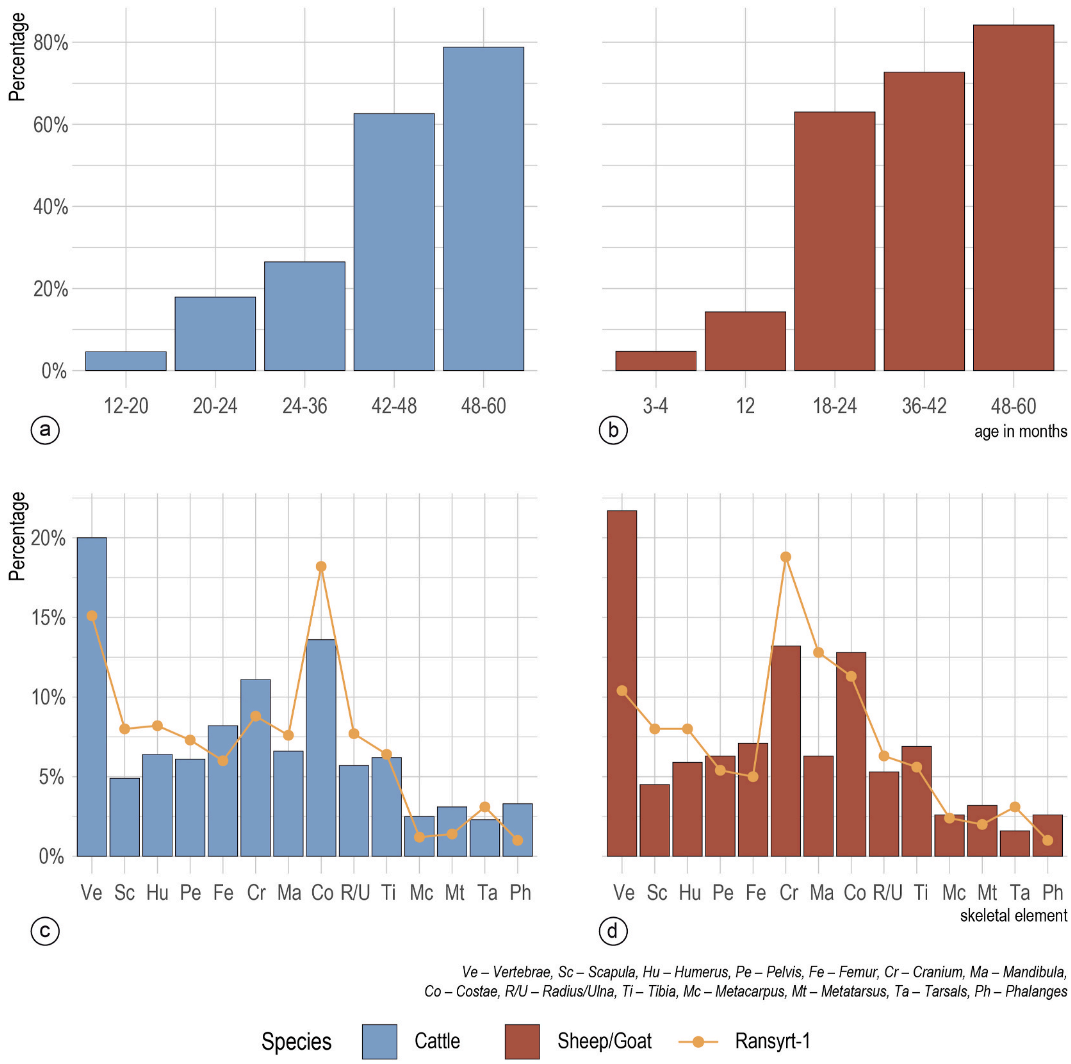

Fig. 5. Characteristics of the animal bone spectrum at Ransyrt-1. a-b Age structure estimated by postcranial elements based on the percentages of open or fusing epiphyses for elements according to five age groups (cf. Table 4); c-d Body part representation by skeletal weight in relation to a reference skeleton total (cf. Table 5).

numbers expected from complete skeletons demonstrates that all body parts of the animals are present.

Bone fragmentation affects individual elements to different degrees. To exclude a taphonomic bias when evaluating the distribution of specimens across the skeleton, relative frequencies of the skeletal elements are assessed by weight. Values calculated for the remains of Ransyrt-1 were compared to those of a reference cattle skeleton (Reichstein, 1994, 27) (Fig. 5c). This evaluation shows that the recovered cattle bones largely follow a normal distribution in relative element proportions by weight. Minor imbalances or deviations of 4–5% exist in vertebrae and ribs.

The ratio of skeletal elements in sheep/goat bones according to the number of fragments and bone weight seems to be similarly evenly represented (Table 5). The degree of fragmentation of sheep/goat bones is also assessed in relation to a reference skeleton (Fig. 5d). In comparison to cattle, it is noticeable that the bones of caprines are less fragmented. Among the elements, similarities can be noted for the relative differences in the degree of fragmentation such as for cattle: the highest fragmentation is found in the muscle-rich or flesh-bearing elements of the extremities; better preserved are also vertebrae and especially the large tarsal bones.

4.1.4. Cattle and sheep size

Measurements of cattle bones reveal a great variability in the animals' sizes (Suppl. Information 2) and two overlapping size ranges that can be addressed as sex groups. Compared to the Neolithic (Benecke, 1994, 51), sexual dimorphism in cattle is no longer particularly pronounced, but to some extent still present, enabling a rough distinction between smaller female and larger male animals in Bronze Age populations. In the Ransyrt-1 material, the size distribution indices indicate a balanced sex ratio, which is in agreement with the morphological analysis.

Since complete long bones are missing, direct calculations of withers heights are impossible. Consequently, body heights can only be estimated approximately. Most of the cattle studied, probably had shoulder heights between 110 and 130 cm.

Several measurements of sheep bones were possible as well, yet also here complete bones were missing, which did not allow the calculation of withers heights. The estimated body height for sheep is between 60 and 70 cm. Goats' size was impossible to calculate.

4.2. Results of the isotope analyses

4.2.1. Strontium isotope data

The $^{87}Sr/^{86}Sr$ ratios of the enamel samples of animal teeth from Ransyt-1 concentrate between 0.70786 and 0.70889 with some variation among the species and few more radiogenic values (Table 6, Fig. 6). Suppl. Information 3 lists the individual data, including geological and

Table 5
Body part distribution based on skeletal elements for the domestic mammals at Ransyrt-1.

Skeletal elements	Cattle	Sheep/Goat	Pig	Horse	Dog
Head					
Cranium (Cr)	469	117	8	–	–
Dentes superiors (Ds)	263	92	4	–	–
Mandible (Ma)	331	130	1	–	–
Dentes inferiors (Di)	217	106	12	3	–
Dentes sup./inf. (De)	–	–	–	–	–
Axial					
Vertebrae (Ve)	1.385	222	–	–	–
Costae (Co)	2.934	619	1	7	1
Sternum (St)	2	–	–	–	–
Forelimb					
Scapula (Sc)	598	114	–	–	–
Humerus (Hu)	430	137	1	–	–
Radius/Ulna (R/U)	478	161	–	–	–
Carpals (Car)	109	29	–	–	–
Metacarpal (Mc)	60	48	–	–	–
Hindlimb					
Pelvis (Pe)	452	77	–	1	–
Femur (Fe)	336	112	1	–	–
Patella (Pat)	41	14	–	1	–
Tibia (Ti)	383	122	–	3	–
Fibula (Fi)	14	2	–	–	–
Tarsals (Ta)	161	85	1	1	–
Metatarsal (Mt)	73	48	–	1	–
Extremities (distal)					
Metapodial (Mp)	34	28	–	–	–
Phalanges (Ph)	131	63	2	–	–
Sesamoid bones (ses)	18	–	–	–	–
Total	8919	2326	31	17	1

archaeological information; summarised information is presented in Table 6. The data of cattle – with the majority between 0.70786 and 0.70876 and a more radiogenic value of 0.70963 – and sheep (0.70805–0.70889) overlap. The Sr isotope composition of pig enamel represents the upper end of the scale of the domestic species with $^{87}Sr/^{86}Sr$ ratios of 0.70851–0.7092. The data range of the domesticated animals only partially coincides with those of the two rodent teeth (0.70834 and 0.70846) sampled to characterize the local bioavailable strontium at Ransyrt-1. This observation suggests that the domestic animals exploited an area near but also beyond the immediate vicinity of the site. The more radiogenic value of a pig tooth with 0.7116 is especially remarkable since these animals are not expected to move long distances and are often considered to represent the bioavailable strontium of the location where their remains were found.

Characterizing the bioavailable strontium at Ransyrt-1 and differentiating the geological units of the North Caucasus are challenging (Table 6, Fig. 6). A few snail shells from Gumbashi-1, a site on Jurassic limestone just 10 km southwest of Ransyrt-1 at 2150 m asl, yielded $^{87}Sr/^{86}Sr$ ratios of between 0.70788 and 0.70799. Twelve samples from different locations represent the Cretaceous plateaus and valleys. Among them, snail shells yielded lower values (0.70743–0.70807) than plants and rodents (0.70817–0.70856). Less radiogenic $^{87}Sr/^{86}Sr$ in snail shells compared to other samples have been reported previously and may reflect a selective incorporation of strontium from calcareous sources, which are important for shell mineralization (Oelze et al., 2011; Maurer et al., 2012). The data of the snail shells from Gumbashi-1, representing Jurassic limestone, overlap with the upper end of the data range of snails from locations of Cretaceous limestone. In contrast, snail shells from locations on Cretaceous sandstone revealed less radiogenic strontium. The data spectrum of the Caucasian foothill zone at ca. 500–800 m asl with sediments of the Eocene and the Oligocene (0.70792–0.70873) also overlaps with the geologically older sedimentary units. The samples available from the foothills of the Mt. Elbrus massive (0.70829–0.70921) originate from a site at the boundary of Devonian bedrock and a Pleistocene lava-field at 2388 m asl. Therefore, they cannot be assigned specifically to one these geological units, which is also the case for the samples from Devonian outcrops and loess (Fig. 6).

The data of cattle and sheep/goat of the neighbouring sites of Kabardinskiy-9 (MBA), Kabardinka-2 and Zubchikhinskoe-7/8 (LBA 2), situated between 1383 and 1461 m asl, generally cover only the upper range of the same species at Ransyrt-1 (Table 6, Fig. 6). Cattle range from 0.70840 to 0.70900 and sheep/goat from 0.70851 to 0.70895. Single teeth of sheep/goat from Zubchikhinskoe-8 (0.70994) and Kabardinka-2 (0.71281 and 0.71293 in the same tooth) revealed more radiogenic values. The data of both teeth are higher than all comparative data and point to foraging outside the covered geological units. Molars that were sampled at two positions along their crowns revealed very similar $^{87}Sr/^{86}Sr$ values. Moreover, there is no noteworthy difference between specimens from the MBA and the LBA 2 at these neighbouring sites. However, as the sample sizes per site are very small this is rather a first observation than a secured statement.

Table 6
Strontium isotope data ranges of the Ransyrt-1 animal samples as well as of comparative archaeological and modern samples from the study area.

Archaeological sites	Cattle	Sheep/Goat	Pig	Dog/Wolf	modern fauna/flora
Ransyrt-1 (LBA1)	0.70786–0.70876 outlier: 0.70963	0.70805–0.70889	070,851–0.70869 outliers: 0.70922, 0.7116		0.70834–0.70846 rodents
Kabardinskiy-9 (MBA)	0.70864–0.70868	0.70853–0.70874			
Kabardinka-2, Zubchikhinskoe-7/8 (LBA 2)	0.70840–0.70900	0.70851–0.70895 outliers: 0.70994, 0.71281–0.71293			
Gumbashi-1 (LBA2)	0.70959–0.70979 0.71344	0.70849–0.70941			0.70788–0.70799 snails
Kudakhurt (fMBA)		0.70832–0.70907		0.70907	0.70766 snail
Modern comparative samples					
Palaeozoic/Jurassic mixture (lower Malka valley)					0.70728–0.70739 snails
Devonian/Pleistocene volcanic mixture (Dzhili-Su, Elbrus)					0.70829–0.70921 plants and rodents
Jurassic (Gumbashi-1)					0.70788–0.70799 snails
Cretaceous (various locations)					0.70743–0.70807 snails 0.70817–0.70856 plants and rodents
Eocene/Oligocene (various locations)					0.70792–0.70873 snails and plants
Pliocene/Loess (Prokhladnaya)					0.70768 snail

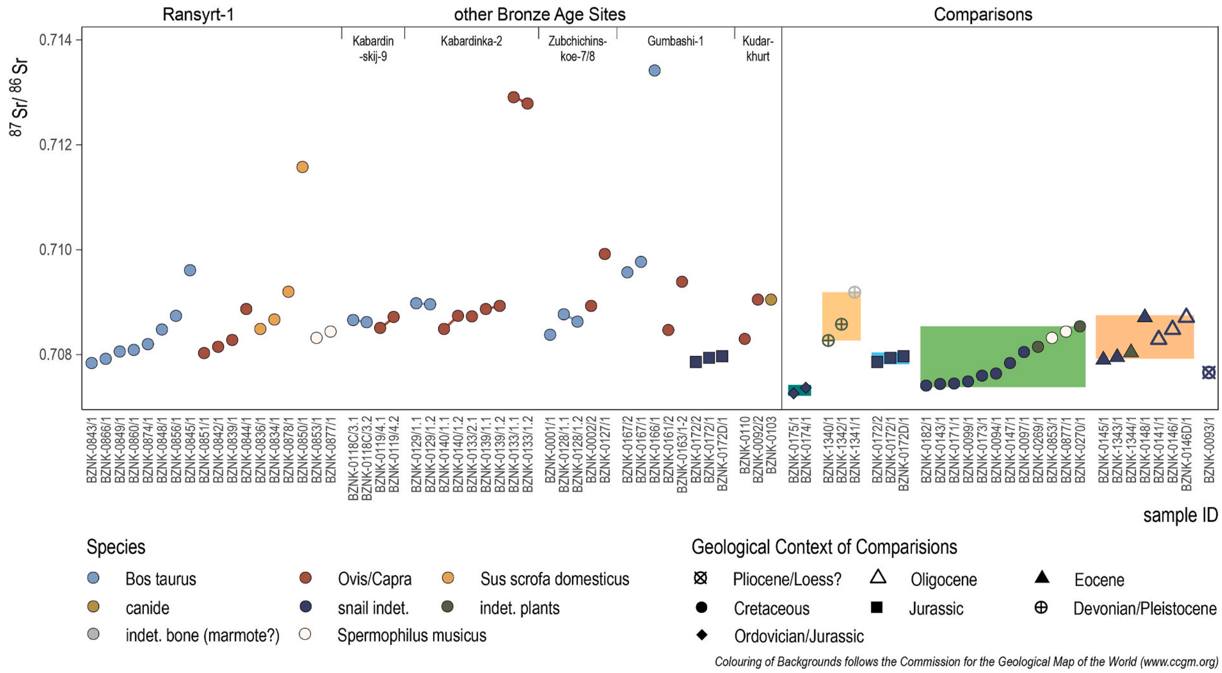

Fig. 6. $^{87}Sr/^{86}Sr$ isotope ratios of samples from Ransyrt-1, Kabardinskiy-9, Kabardinka-2, Zubchikhinskoe-7, Kudakhurt and reference samples. Samples sorted by archaeological sites, comparative, and animal species. Reference samples from archaeological sites are plotted in both parts of the graph.

Despite its distance of about 120 km, the teeth from Kudakhurt located at 734 m asl yielded a similar data spectrum to the other sites. In contrast, the data from Gumbashi-1 were more variable. The $^{87}Sr/^{86}Sr$ ratios of cattle teeth (0.70959, 0.70979 and a more radiogenic outlier of 0.71344) are markedly above most data from Ransyt-1 and the other LBA 2 sites. The analytical values of caprine teeth (0.70849 and 0.70941) are in the upper range or higher than those from the other locations. All enamel data Gumbashi-1 are also well above those of the three snail shells from the site (Fig. 6). The similarity and differences within and among the data from the individual sites must be critically evaluated in the light of the geology, resulting biologically available strontium, topographic locations, and the ancient exploitation strategies that might have changed over time.

4.2.2. *Stable carbon and oxygen isotope analysis of sequentially sampled cattle molars*

The results of the stable carbon, oxygen and strontium isotope analyses are reported in Table 7. Overall, $\delta^{18}O$ values vary between −11.08 and −8.91‰ with an intra-tooth amplitude of variation between 1.28 and 2.87‰. All three specimens show sinusoidal variations along the tooth crowns, reflecting seasonal differences of $\delta^{18}O$ values of meteoric water driven by the seasonal temperature cycle. The $\delta^{13}C$ values vary between −11.94 and −10.06‰ with an intra-tooth amplitude of variation between 0.44 and 0.92‰, mirroring only small seasonal changes in the isotope values of the animals' diet. It is worth mentioning that the $\delta^{13}C$ values of BZNK-845 and BZNK-848 are overlapping, while the $\delta^{13}C$ values of BZNK-843 are higher. In addition, variation of the overall shape of the $\delta^{18}O$ curves among teeth from different individuals can be noted (Fig. 7a-c). The $\delta^{18}O$ pattern of BZNK-843 appears to be opposed to the other two sequences (BZNK-845, BZNK-848), indicating that the animal was different in terms of both birth season and food supply.

Results from the modelling of the three $\delta^{18}O$ sequences (Table 8) show that the length of tooth crown formation over one year (X) varies between 26.92 and 36.11 mm, indicating inter-individual variations in annual tooth growth rate. Pearson's r-values between 0.92 and 1.00 confirm the similarity between the $\delta^{18}O$ values and the modelled data. The location of the maximum $\delta^{18}O$ value in the tooth crowns (x_o) varies from 4.29 to 19.96 mm from ERJ. Although the sample is small, these numbers indicate that calving was not limited to a single restricted period. The birth of two cattle individuals (BZNK-845, BZNK-848) falls

Table 7
Results from stable carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$) and strontium ($^{87}Sr/^{86}Sr$) isotope analyses of cattle lower third molars from Ransyrt-1. Both $\delta^{13}C$ and $\delta^{18}O$ values are reported relative to V-PDB. ERJ = enamel-root junction. Mean values are arithmetic averages of all values measured in a tooth. Δ = values indicate intra-tooth amplitude (difference between maximum and minimum values).

BZNK-843/1					BZNK-845/1					BZNK-848/1				
	ERJ (mm)	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)	$^{87}Sr/^{86}Sr$		ERJ (mm)	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)	$^{87}Sr/^{86}Sr$		ERJ (mm)	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)	$^{87}Sr/^{86}Sr$
1	3.05	−10.17	−10.17		1	4.29	−11.27	−7.51		1	6.54	−11.79	−8.21	
2	6.52	−10.06	−10.20		2	9.58	−10.99	−9.08		2	10.27	−11.30	−9.00	
3	10.66	−10.33	−9.68		3	16.30	−11.26	−10.13		3	15.12	−11.02	−10.46	
4	13.93	−10.42	−9.22		4	22.79	−11.34	−10.01		4	21.05	−11.46	−11.08	
5	19.96	−10.41	−8.91	0.70786	5	28.99	−11.44	−9.18		5	25.30	−11.72	−11.06	
6	24.70	−10.78	−9.50		6	35.93	−11.10	−8.62	0.70963	6	29.52	−11.73	−10.54	
					7	40.63	−11.24	−8.70		7	32.98	−11.69	−9.96	
										8	38.48	−11.94	−9.27	0.70850
Mean		−10.36	−9.61		Mean		−11.23	−9.03		Mean		−11.58	−9.95	
Min		−10.78	−10.20		Min		−11.44	−10.13		Min		−11.94	−11.08	
Max		−10.06	−8.91		Max		−10.99	−7.51		Max		−11.02	−8.21	
Δ		0.72	1.28		Δ		0.44	2.62		Δ		0.92	2.87	

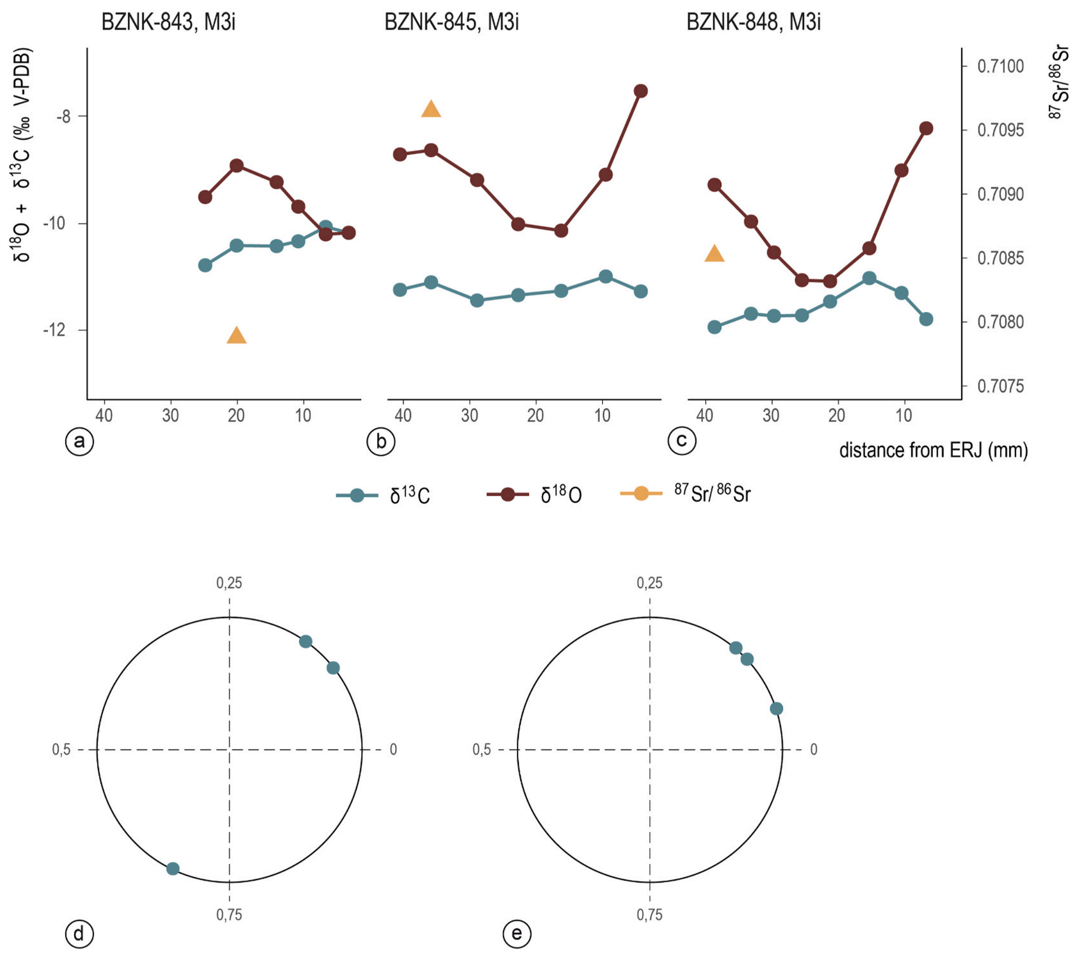

Fig. 7. Seasonality and modelled birth seasons for the cattle teeth analyzed in this study. a-c $\delta^{18}O$ and $\delta^{13}C$ values, and $^{87}Sr/^{86}Sr$ ratios, d-e distribution of cattle birth based on the normalized data set (x_0/X) from modelled $\delta^{18}O$ lower M3 teeth (d) at Ransyrt-1, e comparative modelling of cattle at the Tagkhahovit (South Caucasus) using M2 after Chazin (2016), Table B3, p. 369.

Table 8
Results from the modelling of $\delta^{18}O$ sequences of sequentially sampled cattle third molars from Ransyrt-1.

Specimen	*X* (mm)	*A* (‰)	x_0 (mm)	*M* (‰)	x_0/X	*r* (Pearson)
BZNK-843	26.92	0.68	18.35	−9.55	0.68	1.00
BZNK-845	32.41	1.08	3.33	−9.27	0.10	0.92
BZNK-848	36.11	1.12	5.38	−10.06	0.15	0.96

within the same segment of the year (first quarter defined by $x_0/X = 0$ to 0.25), while the birth of the third individual (BZNK-843) occurs in the third segment (x_0/X quarter = 0.50 to 0.75) (Fig. 7d). The distance between the birth seasons of approximately two quarters of the year is also directly reflected in the $\delta^{18}O$ curves running almost in opposite directions.

5. Discussion

5.1. Animal husbandry practices at Ransyrt-1

The faunal assemblage of Ransyrt-1 consists predominantly of cattle, sheep and goat whose skeletal remains accumulated as waste due to slaughtering, consumption and subsequent deposition. These deposits are related to the activities performed within the central enclosure, whereas animal bone fragments were scarce outside of it (Fig. 2d). Overall, the inventory is extremely poor regarding species, despite its volume. With the exception that most horse and pig bones were recovered from the closing levels and in a limited area south of platform 1, no substantial differences in depositional locations are apparent. Obviously, only the three main species were relevant in Ransyrt 1, either for economic or other reasons. The analyzed remains represent approximately complete animal carcasses, i.e. the animals were slaughtered and exploited directly at the site or in its vicinity.

The intense fragmentation of the bones of muscle-bearing elements indicates intensive exploitation of the carcasses for meat. Subadult and especially young-adult cattle and sheep/goat make up the bulk of the material, whereas younger age groups are absent or severely underrepresented (Fig. 5a-b). Such an age composition does not correspond to typical settlement waste, but rather indicates seasonal use of the site with a focus on the autumn months. This estimate is based on age at slaughter calculations, which refers to regional ethnographic data that demonstrate most animals are born in spring. For traditional pre-modern local cattle breeds, a calving season between late May and June is reported, while most sheep lamb between March and early April (Shamanov 1972; Antipina, 2017). Frosts and winter episodes from mid-October until May are not uncommon on the mountain plateaus above 1500 m asl. Such conditions have a bearing on the birthing period, at least for animals raised at these altitudes.

Estimations of birth distributions of prehistoric cattle in Europe suggest that seasonal calving prevailed during the sixth to fourth millennia BCE. They usually concentrated in three months per year (Balasse et al., 2021), which more or less corresponds to the traditional annual cycle in the pre-modern Caucasus. The three teeth sampled in this study indicate births during two opposite seasons (Fig. 7d-e). A

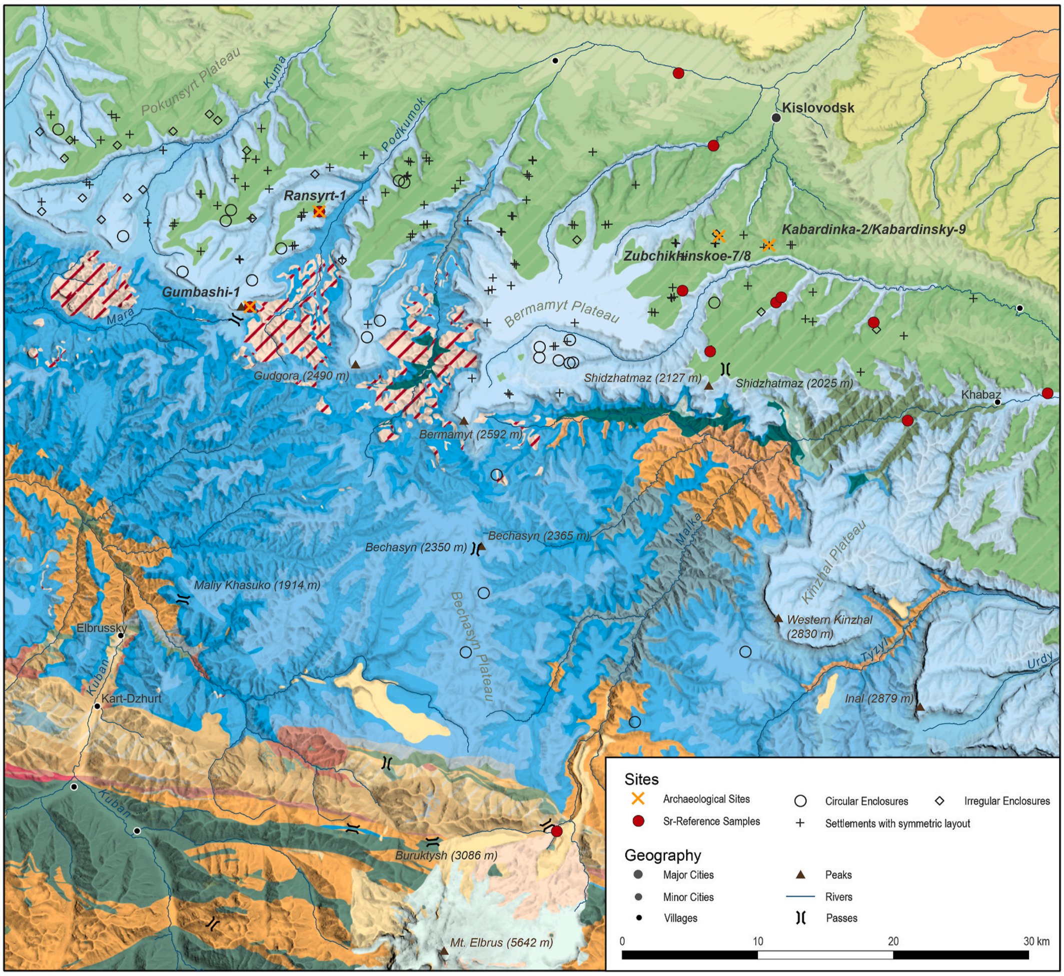

Fig. 8. The geological setting of LBA archaeological sites between Kislovodsk and Mt. Elbrus and major passes used by premodern herders. Archaeological data from Reinhold et al. (2017), fig. 157 and 162. Digital elevation model based on Shuttle Radar Topography Mission 1 Arc-Second, data of modern settlements, mountain peaks, and watercourses from OpenStreetMap. For details of the simplified geological map see Suppl. Information 1.

similar model based on three x_0/X-values of cattle M2s from LBA Tsaghkahovit in the South Caucasus revealed a more restricted calving period (Chazin, 2016, Table B3, p. 369), which corresponds to two individuals from Ransyrt-1 (Fig. 8). The number of investigated specimens at both sites is too small to state whether births were ultimately restricted to two seasons or whether they were distributed more evenly throughout the year. Multi-season reproduction was demonstrated for LBA sheep in the South Caucasus (Chazin, 2021), which might be a sign of human interventions in the reproductive cycle of the animals, indicative for an intensification of animal husbandry strategies in this epoch. Multiple birthing seasons or a longer birthing period suggest a deliberate extension of the time during which animals can be milked. The absence of calves younger than half a year at Ransyrt-1, as well as the absence of bones from foetal and neonatal animals, indicate that calving took place at locations not around or directly at the site. This observation is not biased by excavation practices, as even very small bone fragments were collected.

5.2. Cattle dietary patterns

The enamel of the three cattle teeth sampled in this study exhibited similar carbon isotope compositions with $\delta^{13}C$ mean values between −11.58 and −10.36‰ (Table 7). The range translates to calculated plant values between ca. −26.2 and −25‰ (based on +14.6‰ $\delta^{13}C$ enrichment between diet and enamel bioapatite (Passey et al., 2005). These values clearly correspond to a diet dominated by C_3 plants. The range of values within the teeth of 1.9‰ corresponds to a 1–2‰ variation in $\delta^{13}C$ values plants. Overall, the combination of absolute values and ranges indicates that the animals foraged on C_3 plants regardless of season (Smedley et al., 1991; Hartman, Danin, 2010). This finding is consistent with other evidence of the absence of C_4 plants among the alpine flora of the study area (Knipper et al., 2020).

Two of the $\delta^{13}C$ sequences (BZNK-845, BZNK-848) appear to co-vary with the $\delta^{18}O$ curves (Fig. 7b-c). The $\delta^{13}C$ values of these teeth seem to reflect natural seasonal changes of the isotope data of plants with higher values in the warmer and lower values in the colder months. This observation points to grazing on similar pastureland year-round, with seasonally slightly varying $\delta^{13}C$ values of the vegetation. One tooth (BZNK-843) exhibits higher $\delta^{13}C$ values than the other two, specifically in the colder season. This animal may have moved between different pastures and/or fed on stockpiled plants that had grown in spring and summer during the winter. Feeding animals during winter months with fodder collected in summer, hence ^{13}C-enriched, may result in intra-tooth variation diverging from the usual seasonal trends (Makarewicz, 2017, 2018; Groot et al., 2021).

5.3. Strontium isotopes as indicators for animal mobility

Exploring mobile or stationary husbandry strategies of domestic animals in the past requires the characterization of the isotope composition of the biologically available strontium in potential catchment areas. Strontium may be released from bedrock, whereas weathering clays or other overlaying sediments usually contribute to the budget of strontium that can be taken up by plants (Oelze et al., 2012; Bentley, 2006). Attempts of isotope baseline mapping in the Great Caucasus are challenging due to the varying geological properties of the mountainous landscape (Fig. 3). For the area studied, geochemical studies report few strontium isotope data for Neogene and Quaternary volcanic as well as some Proterozoic basement rocks, such as granites, gneiss or schist that crop out in the central range near Mt. Elbrus (Lebedev et al., 2010). The volcanic lavas range from 0.70540 to 0.70636, whereas various Proterozoic rocks of the Mt. Elbrus basement and the surrounding mountain range vary between 0.71032 and 0.75050. The lavas ca. 150 m away from our sampling site at Dzhili-Su at the border of a Pleistocene lava field and Devonian bedrock range between 0.70569 and 0.70575, while the bioavailable strontium in plants and rodents is 0.70829–0.70921 (Table 6). Other geological units, such as the Jurassic and Cretaceous limestone and sandstone plateaus or the Loess plains of the mountain foreland are much less well investigated.

Ransyrt-1 is situated on a Cretaceous limestone plateau with Jurassic rocks cropping out at the slopes and cliffs below. Our own comparative data for bioavailable strontium are based on snail shells, rodents, and plant material, and the isotope compositions of samples from locations on Jurassic and Cretaceous sediments overlap (Fig. 6). Among them, snails from Cretaceous limestone revealed the lowest values. Focusing on Ransyrt-1, we note that the $^{87}Sr/^{86}Sr$ values of two rodent teeth from the site itself as well as two plants and few snails from other locations on Cretaceous sediments in the wider area correspond to the lower values among those of cattle and sheep (Fig. 6). The data range of the snails from sites on Cretaceous sediments extents to less radiogenic values, which do not occur among the cattle teeth. Since snail shells often tend to exhibit lower $^{87}Sr/^{86}Sr$ values than other samples (Fig. 6), this observation is unsuitable for concluding that the widespread plateau of Cretaceous sediments can be excluded as the catchment area of the Bronze Age cattle herds. In contrast, substantial overlap is found between the data of cattle teeth from Ransyrt-1 and snail shells from locations on Jurassic sediments and the Caucasian foothill zone with Eocene and Oligocene deposits. These comparative data do not differentiate distinct strontium catchments that correspond to specific geological units, a fact that complicates the interpretation of the archaeological data.

According to the geological map, only few kilometres up the Podkumok river, volcanic rocks of Jurassic age crop out at the surface (Marinskiy complex: granite-porphyritic or andesitic-porphyritic) (Fig. 8). Similar outcrops appear in the upper parts of the Ehskakon valley to the east and between the headwaters of the Mara and the Gumbashi cliff west of the archaeological site but at a lower altitude compared to the settlements. Unfortunately, these areas were not targeted when comparative samples were collected due to their generally difficult accessibility. They are also currently not accessible to us. In general, these kinds of bedrock possibly release more radiogenic strontium than the surrounding calcareous rocks (Faure, Powell, 1972). Therefore, pasturing in these areas may have caused the more radiogenic values that appear as outliers among the animal teeth from Ransyrt-1, Kabardinka-2, and Gumbashi-1. However, the relief in the areas of volcanic bedrock differs from that of the plateaus due to steep slopes and a more rugged terrain. They are prone to landslides when not covered by forests. In the plateau zone, flat areas alternate with vertical cliffs and only a few routes lead from the valleys to the highlands. Access to the Ransyrt plateau is mainly possible from the Gumbashi pass (2187 m asl) via a narrow ridge and only few other vertical paths for pedestrians and horses exist. These plateaus and paths are all situated on Jurassic and Cretaceous formations, making it unlikely that the areas of volcanic basement were part of the catchment of the numerous archaeological sites documented on the plateaus, with Ransyrt-1 being one of them.

As hypothesized above, animal consumption at Ransyrt-1 may have been related to feasting during ritual activities by communities from a wider area. We can expect to find patterns of exploitation, since the ritual is a kind of bottleneck in the selection of animals for this special acts. One aspect is the absence of remains of young cattle and sheep as well as presumed slaughter in autumn. In the traditional economies of the region, surplus animals were slaughtered during autumn in order to reduce the number of livestock that had to be fed hay in winter. So, autumn would be a logical time to hold major festivities during which large quantities of meat are consumed. An additional factor is the presence of all skeletal elements in the consumption waste. It indicates that there was no selection of body parts and all bones must be regarded as food remains. The strontium isotope data provide contributing evidence as they are more variable than those of the animal remains from Kabardinsky-9, Kabardinka-2, and Zubchichinskoe-7/8, which represent typical LBA 2 settlements (Reinhold et al., 2017). This hints to a scenario, where animals were raised elsewhere and gathered at Ransyrt-1 for providing food for the ritual activities.

The strontium isotope dataset from Ransyrt-1 includes lower values than those of the other sites. Nevertheless – as discussed above – the biologically available strontium of the different geological units and locations is not distinct enough to allow for any statements about possible areas of origin of the animals. Considering also the light stable isotope data, we observe that cattle individual BZNK-0843, which revealed slightly higher $\delta^{13}C$ values, especially during the winter, and a different trend of the $\delta^{18}O$ seasonal curve, also yielded the lowest $^{87}Sr/^{86}Sr$ value among all sampled teeth. In contrast, the Sr isotope data of the two cattle that presumably grazed on the same or very similar pastures throughout the year (BZNK-0845, 848) are among the highest in the data set. The latter two individuals overlap with the data spectrum of the younger LBA 2 settlements, which are located about 40 km east of Ransyrt-1. The heterogeneity of the data points to different regions of origin or different herd management systems. They match, for instance, the data from the high mountains at Dzhili-Su, even though at an elevation of 2350 m asl year-round pasturing was impossible and therefore the lower parts of Mt. Elbrus are an unlikely place of origin for these animals.

The variability of the $^{87}Sr/^{86}Sr$ ratios among pig teeth – including one extremely radiogenic value – is also remarkable. It points to feeding in locations were igneous, metamorphic or volcanic rocks occur. The nearest possible outcrops occur upstream the Podkumok river, few kilometres away from Ransyrt-1, but are difficult to access and seem unsuitable for rearing pigs. Other areas with Proterozoic or early Paleozoic formations of granites or metamorphic rocks are the headwaters of the Kuban river near Khurzuk or the valley of the Malka river at altitudes of ca. 1500 m asl (Fig. 8). Volcanic outcrops of dacites and andesites of Jurassic age in the Kuban valley south of the confluence of Mara and Kuban rivers near Karachaevsk at ca. 950 m asl are likewise possibilities. Other than the Malka river valley, both parts of the Kuban valley are comparatively wide and flat with forested slopes suitable for rearing pig, and both are connected to the headwaters of the Podkumok river and the Ransyrt plateau via passes. However, we cannot exclude the possibility that particularly the animal with the strikingly high $^{87}Sr/^{86}Sr$ ratio is a wild pig that was hunted in the areas with magmatic outcrops in the vicinity of the site. Apart from that, the restricted occurrence of most pig bones near platform 1 and the prevalence of jaws and teeth might even be related to a specific ritual activity for which the animals were brought to the site.

5.4. Ransyrt-1 in the light of the isotope data of younger LBA sites on the plateau zone

Ransyrt-1, by a century or two, predates the settlements whose populations from the 16th century BCE onwards were gradually developing a very efficient semi-stationary pastoral economy in the mid-height mountains zone south of Mt. Elbrus. Settlements such as Kabardinka-2 or Zubchikhinskoe-7 have an architecture suitable for sheltering large herds, which may also have been wintering in stables, at large central places or in nearby enclosures (Fig. 2e-f) (Reinhold, 2017). Based on estimations of the carrying capacity of the catchments around the settlements, it was postulated that large segments of the herds were pastured beyond the settled territory during summer in order to harvest and store hay from these areas as winter fodder (Reinhold et al., 2017, 152–160).

The isotope data of the animals from all sites near Kabardinka-2 have a more restricted range than those of Ransyrt-1. Most values vary between 0.70840 and 0.70900 for cattle and between 0.70851 and 0.70895 for sheep/goat with only two outliers, and most of these data overlap with the upper parts of the data range at Ransyrt-1. Variation within and between both species is low. Furthermore, cattle and caprine teeth with two sampling points each revealed very similar data, which is also the case for the outlier caprine from Kabardinka-2 with values of 0.71281 and 0.71293. Accordingly, these findings do not indicate that individual animals used pastures of different geological properties. Seasonal mobility between landscapes of significantly different character and the necessity of covering considerable distances in between is not directly reflected in the isotopic data. However, because the bioavailable strontium at pastures of different elevation is also very similar the data are somewhat ambiguous and – at least at the current state of research and comparative data collection – spatial resolution is too low to either confirm or to reject the hypothesis of mobile herding. Archaeological arguments for seasonal herding are potential alpine summer locations with circular enclosures and contact finds of sites in high mountain locations (Fig. 2 h; 8). Possible sources of the more radiogenic strontium as documented by the outliers correspond to those discussed above for Ransyrt-1.

The lower data range of Ransyrt-1 for cattle and sheep are noticeably missing among the samples from the other sites. This is a remarkable difference between the chronologically older and younger locations. Perhaps some of the animals ending their life at Ransyrt-1 came from the Caucasian forelands, which were not visited by LBA 2 herders. During this epoch, archaeological sites in the valleys and the foreland zone are virtually absent.

Furthermore, it is interesting that the $^{87}Sr/^{86}Sr$ data of the animal teeth from the later site of Gumbashi-1 is mostly more radiogenic and more variable in comparison to those of the other sites. Gumbashi-1 is located above the eponymous pass that leads from the Kuban valley via the Mara and Podkumok rivers to the Caucasian Mineral Waters area (Fig. 8). At the same time, routes leading across various watersheds to the lower flanks of Mt. Elbrus and via the Bechasyn plateau to the valley of the Malka river branch off. This communication network makes it possible that – similar to Ransyrt-1 but for different reasons – non-local animals were more frequent here than at other places. Excavations at Gumbashi-1 documented a similar archaeological spectrum as in Kabardinka-2. Although the topography and settlement plans are somewhat different (Fig. 2 e; g), Gumbashi-1 can be considered a regular settlement site (Reinhold et al., 2017).

5.5. LBA animal herding strategies in the Caucasus

The LBA throughout the Caucasus is characterized by a significant change in settlement patterns and livestock management (Chazin, 2016; Reinhold et al., 2017). The reconceptualization of lifeways from mobile to stationary becomes visible from the 17th century BCE onwards in the south (Narimanishvili, Amiranashvili, 2010) and the 16th century BCE onwards in the north (Reinhold, 2017). Prior to this, only few settlements are known from the South Caucasus, among them Didi Gora (Georgia), a site where an MBA archaeozoological assemblage was investigated (Uerpmann and Uerpmann, 2008). After the initial development of stationary camps, the respective populations on both sides of the Caucasus developed complex settlement systems with village-like sites including architecture designed for animal herd management in the 15th/14th centuries BCE (Reinhold, 2009). In the North Caucasus irregular enclosures in-between settlements, walls separating possible pastoral territories and circular enclosures outside the settlement areas are documented in high-mountain elevations (Reinhold et al., 2017) (Fig. 8). In the South Caucasus complex systems of enclosures are reported for Tsaghkahovit. They are considered evidence of a semi-mobile, pastoral population segment that is only seasonally (?) present at the site (Lindsay et al., 2009).

In the North Caucasus and in the 18th/17th century BCE, the site of Ransyrt-1 illustrates a prelude to this process, representing communities, which have not yet settled down. If we therefore consider the animal bone spectrum of Ransyrt-1 in the light of other MBA and LBA sites on both sides of the Caucasus, further details of this process emerge.

There are only few well-investigated animal bone assemblages available from this epoch: LBA spectra, which are contemporaneous to Kabardinka-2 (Reinhold et al., 2017, 248) are available from Lesnoe in the Northwest Caucasus (Antipina, 2011), Udabno I, Didi Gora and Tqisbolu Gora in eastern Georgia (Uerpmann, 2006; Uerpmann, Uerpmann 2008), from Aradetis Orgora in central Georgia (Barbiero and Rova, 2020), and the Armenian sites of Gegharot, Tsaghkahovit (Chazin, 2016) and Horom (Obermaier, 2006). Not all of these can be considered in the discussion due to differences in the data published.

Among these localities, Kabardinka-2, Gegharot and Tsaghkahovit share a dominance of caprines (Fig. 9), whereas cattle make up less than 40% and remains of wild animals are very rare. In terms of meat yield, however, cattle were the most important species, as the mass equivalent of cattle to sheep is about 1:8 (Antipina, 2017). There are also similarities in animal husbandry techniques between the North Caucasus sites such as Kabardinka-2 and animal management at Tsaghkahovit or Udabno I, including the use of pastoral architecture like enclosures or the use of multi-functional houses for stabling animals in winter (Bertram, Bertram, 2013).

Udabno I revealed a significantly lower percentage of cattle bones than the Armenian sites, but many pigs remains. The Lesnoe, Aradetis Orgora and Didi Gora MBA and LBA faunal inventories only comprise ca. 20% of caprines but over 60–70% cattle bones (Fig. 9). These sites are located in more forested and humid microregions well suited for cattle rearing. Thus, despite of similar trends in settlement developments and the emergence of pastoral architecture, LBA livestock management tended to be flexible, depending on local conditions and possibly on specific strategies that favoured either large or small herds.

Compared to the relative proportions of species at all sites, Ransyrt-1 stands out with nearly 79% of the animal remains belonging to cattle and only 21% to sheep/goat. At Kabardinka-2, which is located in a comparable environment, the percentages are more similar, with 51% cattle and 40% sheep/goat. In Udabno I and the two Armenian sites Tsaghkahovit and Gegharot, the proportions of cattle and sheep/goat are also somewhat more balanced. The comparison of species proportions illustrate that the assemblage of Ransyrt-1 does not correspond to the usual domestic spectra in settlements. The reason for this is the suggested intentional selection of species or environmental factors. The discrepancy between the bone assemblages from Ransyrt-1 and Kabardinka-2 renders the latter rather unlikely.

Differences in the slaughter ages of animals between the sites are likewise informative (Fig. 10). In Ransyrt-1, in contrast to the other places, infant cattle (0–1 year) are completely absent, and for sheep/goat the relative proportion is only 4%. In contrast to Kabardinka-2 or Lesnoe, there are also no cattle over six years of age (senile) in Ransyrt-1. The first two sites document self-reproducing, stable herd populations (Antipina, 2017). The absence of cattle individuals in their first year of life at Ransyrt-1 speaks against a self-reproducing population. It is instead more likely that rearing of the animals occurred in a distance from the site and the "herd" at Ransyrt-1 is indeed an accumulation of individuals that were purposefully brought to the site from elsewhere. The strontium isotope data, which at Ransyrt-1 are more variable than at typical settlement sites as well as the carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope data of the small subsample of teeth point in the same direction. Furthermore, the data indicates that ritual activities contributing to the

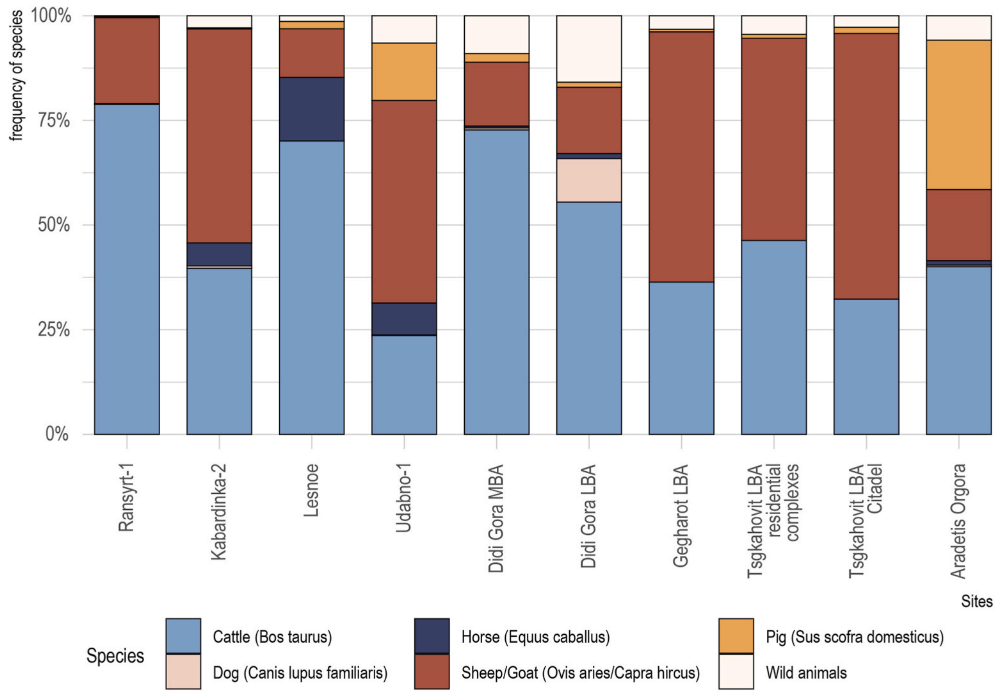

Fig. 9. Ransyrt-1 and other Caucasian MBA and LBA sites. Species ratios calculated by NISP. Data from this study, Antipina (2011); Antipina (2017); Barbiero, Rova, 2020; Chazin (2016); Uerpmann (2006); Uerpmann and Uerpmann (2008).

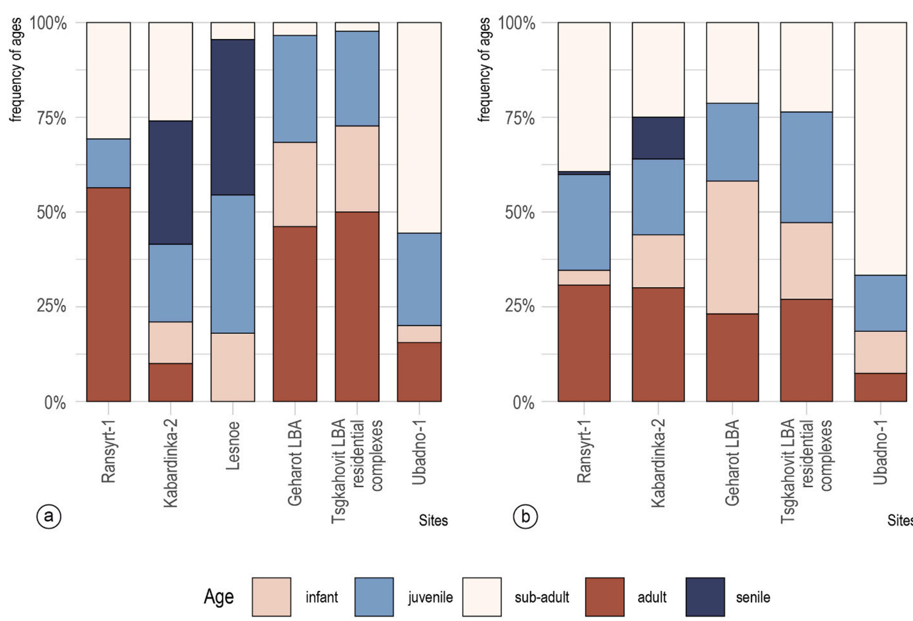

Fig. 10. Ransyrt-1 and other Caucasian MBA and LBA sites. Age structure calculated by epiphyseal fusion and tooth wear. A Cattle b Sheep/Goat. Data from this study, Antipina (2011); Antipina (2017); Barbiero, Rova, 2020; Chazin (2016); Uerpmann (2006); Uerpmann and Uerpmann (2008). For the Lesnoe site, archaeozoological data for age determination is available for cattle only.

animal bone assemblages at Ransyrt-1 took place outside the expected birthing seasons of cattle and caprines. This is supported by the sheep/goat age structure and the frequent butchery of animals in the second half of their second year of life (Fig. 5a-b).

Nevertheless, most of the animals slaughtered at Ransyrt-1 were 2–5 years old (Fig. 5 a; 10. a). Given the presence of cows and the absence of calves, milk production might not have been an important factor. However, in light of the modelled $\delta^{18}O$ sequences, husbandry practices focused on milk production, wherever the cows may have been raised. The age structure of cattle in Ransyrt-1 suggests a preference for animals with the best meat yields. This is likely a result of selection for ritual consumption or the beginning of a more meat-oriented exploitation strategy, as postulated by E. Antipina for the exploitation of the LBA 2 cattle at Kabardinka-2 (Antipina, 2017). The majority of caprines at Ransyrt-1 reached an age of 3–5 years, again indicating the use of secondary products such as milk and wool in the herds from which they originated (Payne, 1973; Helmer et al., 2007). A similar strategy is suggested for Kabardinka-2.

6. Conclusion

The multi-proxy analysis revealed that the animal bone assemblage of the LBA 1 site of Ransyrt-1 is rather poor in species diversity, despite of its volume. Cattle, sheep and goat of subadult and adult ages dominate the inventory, and only a few remains of horses, pigs and wild animals were recorded. With regard to the archaeological context, no substantial differences in the relative frequencies of species can be observed between structures and platforms. The distribution of skeletal elements indicates that the animals were slaughtered, prepared, consumed and deposited at the site, obviously in a ritual context. This context gathered LBA communities of different origins from the mountains, which might have included even the lower course of the Kuban river (Reinhold, et al. 2020). Due to the lack of camp or settlement sites, we can assume that they maintained a mobile lifestyle.

Strontium isotope ratios of cattle, sheep and pig teeth are more variable compared to teeth from typical settlement sites, an observation, which – along other evidence – points to a heterogeneous assemblage of animals originating from different populations at Ransyrt-1. Pinpointing specific areas of origin of these animals, however, proved challenging. The isotopic data represent individual animal biographies, and the studied quantities are not yet large enough for coherent pattern. Comparative data of snail shells, small mammals and plants revealed overlapping ranges of the isotope compositions of the bioavailable strontium at locations of Jurassic, Cretaceous and Tertiary limestone and sandstone, and only few sampling spots from igneous or volcanic bedrock. Moreover, a possible bias of Sr isotope ratios in snail shells towards Sr of calcareous origin may also limit the distinction of the dominating geological units and the interpretation of the isotope data of the archaeological animal teeth. Building on these observations and the recently available detailed geological maps of the area, future research needs to extend the efforts of baseline mapping of the most widespread geological units as well as areas with a dense archaeological record of the MBA and LBA.

First indications for two different birth seasons of cattle as well as slight differences among the $\delta^{13}C$ of three sequentially sampled cattle teeth add to the impression of heterogeneity. Future studies shall extend the sample of cattle teeth and include sheep and goats as well as specimens from other locations. Indications of seasonal variation in animal diets and similarities or dissimilarities among different animals as well as sites will add to the comprehension of the Bronze Age pastoral management. Although the faunal assemblage of Ransyrt-1 differs from those of other sites by a strong focus on cattle, due to ritual activities involving mass meat consumption, some details show that the herding system from which the animal originated anticipated the exploitation structures of the following LBA 2 in the North Caucasus study region with its intensive livestock breeding and mountain agricultural system (Antipina, 2017; Reinhold et al., 2023).

Both North and South Caucasian animal bone spectra of the LBA period illustrate that herd organization and reproduction were highly manipulated by herders, adapting to local ecosystems but independent of the respective cultural affiliations (Chazin, 2016, 2021). Strategies included the use of pastoral architecture allowing the separation of male and female animals or juveniles (North Caucasus, Tasaghkahovit), sheltering animals in stables during winter (Kabardinka-2, probably Udabno 1), semi-mobile grazing practices (North Caucasus, Armenian highlands), or manipulating the animals' reproductive cycle (cattle: Ransyrt-1, sheep: Armenian highlands). Evidence of different birthing seasons within the annual cycle indicated by only one cattle individual does not allow nuanced conclusions. Nonetheless, this result is perhaps an indication that multi-season reproduction practices began as early as the 18th/17th century BCE, when the human population of this region had not yet begun to settle in permanent sites with stone architecture.

Combining all analytical results supports the hypothesis that Ransyrt-1 was a ritual site where large feasts took place that included the consumption of large amounts of meat and other food. Domestic animals from different herd populations and areas were consumed, and there are first indications of distinct herding strategies, which are relevant for the subsequent development of sedentary, semi-stationary mountain agriculture in the Caucasus.

Author contributions

Sabine Reinhold: Conceptualization, Methodology, Formal Analysis, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Supervision, Project administration, Funding acquisition. Jana Eger Conceptualization, Methodology, Formal analysis, Writing – Original Draft, Writing – Review & Editing. Norbert Benecke: Methodology, Formal analysis, Data Curation, Writing – Original Draft. Corina Knipper: Formal Analysis, Writing – Original Draft, Writing – Review & Editing. Dirk Mariaschk: Data Curation, Investigation, Visualization. Svend Hansen: Funding acquisition. Sandra L. Pichler: Funding acquisition, Writing – Original Draft. Claudia Gerling: Writing – Original Draft, Writing – Review & Editing; Aleksandra P. Buzhilova: Funding acquisition. Tatyana A. Mishina: Investigation. Dmitriy S. Korobov: Funding acquisition, Resources, Investigation. Andrey B. Belinskiy: Conceptualization, Resources, Investigation.

Data availability

All datasets related to this article can be found in the Supplementary Information 2–4 and the tables in the text.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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